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Hanford Tank Farms Vadose Zone Monitoring Project

Retrieval Monitoring System Operational Test Plan Results

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Prepared by
S.M. Stoller Corporation
Grand Junction, Colorado

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Prepared By:

________________________________ ____________________

Arron Pope, Logging Engineer | Date
S.M. Stoller Corporation, Hanford

Concurrence:

________________________________ ____________________

Rick McCain, Technical Lead | Date
S.M. Stoller Corporation, Hanford

Approved by:

________________________________ ____________________

Brian Mathis, Manager | Date
S.M. Stoller Corporation, Hanford

1.0 Introduction

In 1994, the U.S. Department of Energy (DOE) Richland Operations Office (DOE-RL) requested the DOE Grand Junction Office (GJO), Grand Junction, Colorado, to perform a baseline characterization of gamma-emitting radionuclides in the vadose zone at all Hanford single-shell tank (SST) farms using high resolution spectral gamma-ray logging methods in existing boreholes surrounding the tanks. In 1998, Congress established the Office of River Protection (ORP) at Hanford, an autonomous organization that reports directly to DOE Headquarters. ORP is responsible for managing all aspects of the Tank Waste Remediation System (TWRS) project, including characterization of the vadose zone potentially impacted by the SSTs. The responsibility for the baseline characterization project, originally under the auspices of DOE-RL, was transferred to ORP in December 1998.

The baseline characterization project provided evidence that gamma-emitting radionuclides have migrated within the vadose zone beneath the tanks in the past and may be continuing to migrate. In response to these findings, ORP authorized MACTEC-ERS and its successor S.M. Stoller Corporation (Stoller) to establish and manage a spectral gamma monitoring program within the single-shell tank farms at Hanford that is performed via logging in the existing monitoring boreholes. The Radionuclide Assessment System (RAS) has been used since fiscal year (FY) 2001 to perform this monitoring.

In FY 2003, ORP's focus changed from stabilizing the existing waste in the tanks to waste retrieval from the tanks. This change in focus also redirected the primary scope of the RAS from routine monitoring to leak detection, monitoring, and mitigation (LDMM) in support of the waste retrieval projects. The LDMM requirements also include the use of a neutron moisture logging system (NMLS) to detect moisture in the vadose zone that may be attributed to the waste retrieval process. Current logging equipment requires that separate log runs be made for gamma activity and moisture. Stoller proposed during FY 2003 that a logging system capable of collecting gamma and moisture data simultaneously in a single log run should be developed to support the retrieval projects. Initially, a truck-mounted system was proposed, but procurement limitations on new vehicles resulted in a portable logging system. This system would be developed from readily available logging equipment. It would significantly reduce the cost of the monitoring for the retrieval projects and free the RAS and NMLS to perform the work for which these systems were originally intended.

Stoller was given the approval to procure the Retrieval Monitoring System (RMS) during FY 2004. Stoller evaluated several existing small-diameter logging systems. The system manufactured by Mount Sopris was identified as the best fit for retrieval monitoring purposes. The "triple-gamma" logging system has the capability for the greatest measurement range in gamma activity, and the sonde can be configured to include a neutron source and helium-3 detector comparable to the moisture logging equipment currently in use in the Hanford tank farms. A formal test plan was developed to assess all aspects of this system against performance criteria prior to its initial use for the retrieval-monitoring program.

2.0 Purpose

The RMS operational test plan (OTP) specified tests to determine the RMS response and overall performance under field conditions (DOE 2005). The purpose of this report is to document the results of testing defined by the OTP. The major tests were associated with the following:

- detector response
- depth control
- verification spectra
- data handling
- logging speed

The results of the tests will be utilized to establish routine operational and data handling procedures. Certain tests revealed minor system deficiencies that required modifications or additions. This report discusses the results, and the modifications or additions made to correct the deficiencies.

3.0 RMS Description

The RMS surface equipment consists of a portable winch and electronics console that is operated from a ruggedized laptop computer, powered from a Honda 2000W inverter-type generator. The surface equipment weighs approximately 150 pounds and is mounted in the bed of a Model 430A Cub Cadet 4X2 Utility Vehicle (HO-01M-00180) that has been fitted with a canopy equipped with side-access doors for weather protection. The downhole sonde consists of a combination of a standard gamma tool (2GHF-1000 Triple Gamma Tool) combined with a custom-designed neutron moisture tool equivalent to the Campbell-Pacific neutron moisture gauge. The sondes are 1.5 inches (in.) in diameter, with a combined length of about 8 feet (ft), and a combined weight of about 22 pounds.

Most RMS operations are conducted using a Panasonic CF-W2 “Toughbook” laptop personal computer (PC), which is loaded and configured with the off-the-shelf Mount Sopris MSLog software package. The PC, which uses the Microsoft Windows XP operating system, stores the log data for later processing and provides displays to allow the operator to monitor the data flow. Depth data and count rates from each detector are combined within the PC and stored internally on a hard disk. Data are transferred to a portable USB flash drive at the completion of monitoring.

The gamma detector is the Mount Sopris 2GHF-1000 “triple gamma” sonde. This sonde measures gamma activity with three different detectors. The most sensitive detector is a 1.5-in.-long NaI crystal and photomultiplier tube. Two different pairs of Geiger-Mueller tubes are installed above the NaI detector. The count rate output for the ZP1200 G-M detector pair is about 1% that of the NaI detector, and the count rate output of the ZP1320 G-M detector pair is about half that of the ZP1200 detectors. This sonde has been used successfully to determine ore grade for U_3O_8 concentrations as high as 20 percent. Counts from all detectors are concurrently recorded. The data are digitized in the sonde and transmitted to the surface via the digital modem/power supply.

The neutron sonde (CPN DX Neutron Probe) is a modified Campbell Pacific Nuclear soil moisture gauge. This probe has been modified to attach to the bottom of the 2GHF-1000 "triple gamma" sonde. The signal from the CPN probe is a pulse output with the pulses being negative voltage value with respect to the cable armor. This signal from the CPN probe is then sent to a DX pulse counting card where the counts per second are combined digitally and sent up the cable through a 2SMA modem section. The modified sonde contains a 50-mCi AmBe source, with a source to detector spacing of 3 in. (7.5 cm).

4.0 Test Results

The following sections summarize the results from each test. Deviations from the test procedures are also described in the following sections. Test result sheets for the individual tests are included in Appendix A.

4.1 Field Verification Test Results

Field verification measurements are required prior to and after a logging event with a particular tool to verify that the tool is functioning within given parameters. During verification, the sonde is inserted into the tool rack such that the bottom tool (moisture gauge) is placed in the source pig, and the gamma detectors are centered opposite the gamma check sources. The tool is allowed to count for a specified time. After the time has elapsed, the count rates from each detector shall be compared with acceptance criteria to determine if they fall within the specified limits. Acceptance criteria will be developed during the system's annual calibration and will not be available during this test. The purpose of this test is to determine if the verification procedure is acceptable, if the pig will produce adequate neutron scattering, and whether the gamma sources are sufficient for all detectors.

Several functions were checked during this process. First, does the software allow the operator to identify the data file as a pre-survey or post-survey verification? Will the files save properly? Does the software allow the operator to extract count rates in the field?

An important part of this test was to determine if the MSLog software allowed the user to extract the count rates from each tool, which could then be compared to acceptance criteria (being developed). Testing showed the software does not provide this feature during or after the pre/post verification. MSLog is an off-the-shelf software package, limiting the possibilities of further tailoring the software. However, the data are saved in ASCII formatted text files, which allowed for an Excel spreadsheet to be developed to accept imported data for direct comparison with the acceptance criteria. Upon import of the data, the spreadsheet immediately evaluates the data, and indicates a pass or fail condition to the operator.

A second part of this test was to determine whether the neutron field verifier would scatter neutrons adequately for use as a field verifier, and whether the thorium-rich lantern mantles used as gamma sources would provide adequate gamma flux for each detector. Evaluation of data acquired during this test indicated that the gamma flux was adequate for the NaI detector and the two paired Geiger-Mueller detectors, and neutron scattering was more than adequate for use as a verifier for the neutron moisture tool.

During the testing it was determined the MSLog software allows the operator to identify verification spectra as a pre-cal or post-cal by changing the acquisition settings to acquire in "time mode", and by using a predetermined pre- or post-cal designation in the file name. The software properly saved the data in the *.las and *.rd formats. A batch file was written after operational testing was completed to allow data to be copied automatically from a specified directory on the laptop hard drive to the data transfer device (a portable USB flash drive). Testing of this showed that as long as the data are saved to the specified folder during logging, transferring data to the USB flash drive using the batch file works quickly and flawlessly.

4.2 Depth Control Test Results

Accurate depth control is essential when evaluating possible contaminant movement in the vadose zone. The performances of two RMS components were evaluated while testing the depth measurement and recording systems. An optical depth encoder located on the winch provides electronic signals to the Mount Sopris MGX II console, and depth is displayed on the console readout, as well as on the computer. To test these components, a steel tape was attached to the zero reference on the sonde, and a series of measurements were acquired in a borehole. Measurements from the tape were compared to the console readout and computer display values. The depth control testing was performed in borehole 299-W10-72 in the 200 West Area. During the testing, the tool was zeroed at the top of the casing and lowered into the borehole. Depths from the digital readout, computer, and steel tape were recorded every 10 ft while lowering the tool into the borehole and while moving the tool back to the surface. The depth return error, or the difference between the tool zero reference and the top of the casing when the tool returned to its starting position, was measured and recorded. The summary sheet for the testing is included in Appendix A.

Testing identified a minor operational deficiency with the Mount Sopris MX winch. The winch lacks a load sensitive device that stops the winch at the bottom of the borehole and when it returns to the surface. Such a feature would prevent cable backlash on the winch drum when the bottom of the borehole is reached, and would prevent the cablehead from being pulled through the top sheave wheel when the tool reached the surface. Careful monitoring of the depth of the tool in the borehole should be sufficient to prevent either of these two scenarios. Brightly colored tape was used to mark the cable at the 10- and 2-ft distances from the cablehead to provide additional visual cues to slow the ascent of the tool when nearing the top of the borehole.

The OTP specified that all depth readings should be within 0.10 ft (tape measurement versus system readout) (DOE 2005). The largest depth error was ¾ in. (0.06 ft), well within the required range. During detector response testing, it was determined that the depth on the computer is refreshed at a rate dependant on the logging interval chosen using the MSLog software. Depth information, including logging speed, is apparently only updated when the tool reaches a new interval. The longer the interval (and the slower the logging speed), the slower the depth and speed refresh rates. The summary sheets for the depth control tests with the winch and winch controller are included in Appendix A.

An additional minor problem was identified regarding the way the software converts between meters and feet — the software was coded using meters, but allows the user to select measurements in feet. Using a logging interval of 0.25 ft (the standard interval to be used when logging with the RMS), a conversion error of approximately 0.0012 ft carries through, making the actual logging interval 0.2488 ft. Though only off by 0.0012 in. per quarter foot, this results in significant deviations from the desired logging interval during long logs: approximately 0.05 ft per 10 ft of logging. To correct for this, it was determined that setting the logging interval to 0.251 ft results in an actual logging interval of 0.2502 ft, which does not deviate nearly as much from the desired interval: less than 0.01 ft per 10 ft of logging.

The winch must also be able to hold the logging sonde at a constant depth while the winch control is in the stop position. This is necessary for the system to make stationary measurements in a borehole. The winch was able to hold the detector stationary when placed into hold mode, but allowed the winch to descend slowly when in "depth up" or "depth down" modes with the winch speed dial turned to the minimum setting. There is a lag time of a little over a second between when the winch is placed in hold mode and when the tool actually becomes stationary, resulting in an additional drop of approximately 0.07 ft. It was determined that the winch operator could correct for the additional drop by placing the winch in hold mode approximately 0.07 ft above the desired stop depth.

4.3 Winch Speed Control Test Results

Most routine logging will be performed in the continuous logging mode. Speed control is vital for producing data with relatively consistent count times in the continuous logging mode. Winch speed control was evaluated during this test. The operator must be able to adjust and control the winch speed while moving the sonde. The OTP specified that the winch must be able to maintain speeds as low as 1.0 ft/min and as fast as 20 ft/min (DOE 2005). The speed of the winch can be monitored on the laptop. At 1.0 ft/min, the speed should not fluctuate more than +/- 0.1 ft/min; at 20 ft/min, the speed should not fluctuate more than +/-2 ft/min. A stopwatch was used to check the speed during this test.

High speed and low speed testing were performed separately. Both tests were conducted in borehole 299-W10-72. The sonde was lowered into the borehole at a rate of 19.77 ft/min and the time to move from 50 to 110 ft was timed with a stopwatch. The sonde was withdrawn from the borehole at a rate of 2.0 ft/min and the time to move from 100 to 50 ft was timed with a stopwatch. The rate displayed on the computer, the time measured with the stopwatch, and the calculated rates were recorded on the test summary sheet. On the second day of testing, an additional winch speed test was conducted concurrently with one of the detector response tests, logging up at 1.0 ft/min from 100 to 20 ft. The calculated rates of speed were within the 10% error for all three tests as specified by the OTP. Test results summary sheets from the tests are included in Appendix A.

It was difficult to dial in an exact rate at slow speeds with the Mount Sopris winch controller because 1) the speed display on the computer was refreshed slowly and appeared to change in increments of approximately 0.05 ft/min, and 2) the speed dial is extremely sensitive to adjustments at slow speeds. The refresh rate is inextricably linked to the logging interval. So at 1.0 ft/min with a 0.25-ft interval, the speed display on the computer refreshes every 15 sec. The speed readout also slowly changed with depth (increasing on the way up) with the speed control potentiometer set at one position, presumably as a result of diminishing load as cable was removed from the borehole. From experimentation during the slow speed tests, it is clear that the lowest logging rate achievable with the Mount Sopris 4MXB-1000 Winch and Controller is 1.0 ft/min. Due to the time required to stabilize the logging speed when first starting to log, it was concluded that logging should be started at least 2 to 3 ft below any critical depth interval, if possible.

Attempts were made to log downward during one of the detector response tests, and it was found that with the speed dial set to the minimum setting (zero), the tool descended under its own weight at approximately 3 ft/min. Analysis of the data from that test indicates that a speed of 3 ft/min is too fast to acquire data of the quality required of the system. Therefore, all logging must occur in an upward direction in order to achieve the slower logging speeds.

4.4 Log Header Test Results

Prior to each log run the operator completed a log header using the computer. The log header contains information regarding the borehole, the date, pre- and post-survey verification, the operator conducting the survey, and the file name. This test evaluated the MSLog logging software's ability to complete and save the log header information. The test result summary sheet for this test is included in Appendix A.

The OTP specified that with the tool energized, the operator should initialize the logging program and attempt to enter all borehole and logging information into the log header (DOE 2005). While doing so, the operator should note any errors or limitations in the software, ease of its use, and whether entries in all fields are required. If a field is not required or is redundant, the software allows for modifications to remove the field, and likewise for fields to be added as necessary.

Log headers were used several times while performing the various tests. Notes regarding the software and the validity of the data fields were written on the data summary sheet. All data fields presently included on the log header are essential information for logging and subsequent analysis. The software does not save the log headers as individual files. Rather, they are attached to the ASCII data files generated during logging. There is an option to pull up the last header information used by clicking the "Last" button in the header window of the software. This function can save time when certain pieces of information in the header are occasionally or routinely the same.

4.5 Detector Response Test Results

This test was performed in borehole 299-W10-72, which is located in the T-7 Tile Field in the 200 West Area. This borehole was selected because it intersects zones of moderate to high ^{137}Cs contamination, which is the major radioactive contaminant in the tank farms. Prior to RMS operational testing, borehole 299-W10-72 was logged with the SGLS, NMLS, and HRLS logging systems in order to provide concentrations of various radionuclides, gross-gamma profiles, and a moisture profile of the borehole against which to compare the RMS data. According to the OTP (DOE 2005), in order to pass this portion of the test there should be no computer lock-ups during logging, and the total gamma and moisture profiles should mimic the profiles provided by the SGLS and NMLS logging.

During detector response testing, sections of this borehole were logged multiple times at different logging speeds and intervals in order to determine the most efficient and effective parameters for simultaneous data collection with all four tools. Log runs were performed primarily using combinations of 0.25-ft and 0.50-ft sample intervals at logging speeds of 1.0 ft/min and 2.0 ft/min because prior logging experience suggested that these two settings would provide the best data. Another constraint on selecting a logging parameter combination was comparability of RMS data and data from other logging systems that have been used in the tank farms in the past. In particular, moisture data is generally collected at 1.0 ft/min with 0.25-ft logging intervals. The high-rate section of the borehole was logged to assess the upper gamma activity limits for each of the gamma detectors, and the susceptibility of the neutron detector to gamma interference. One additional test was performed logging downward using a 0.50-ft depth interval at approximately 3.0 ft/min, which turns out to be the minimum speed when logging downward.

The OTP (DOE 2005) called for a 10-ft repeat section to be logged with each tool after the appropriate logging speed and data collection interval have been selected in order to test the repeatability of the system. During the different tests, intervals were logged with significant overlap. Therefore, it was decided that sufficient overlapping data had been collected to assess repeatability, and that specific repeat sections were not necessary.

There were no computer lock-ups while performing these tests. Analysis of the resultant data indicated that in order to achieve both the best precision and the easiest (best) comparability with prior data, a depth interval of 0.25 ft and a speed of 1.0 ft/min are the appropriate parameters.

Data gathered at the Hanford Calibration Models showed that the first data points acquired with any and all tools during any given log were often spurious. All subsequent data acquired during the same log were meaningful. Our conclusion is that the first line of data from any log should be thrown out as a rule.

4.6 Data Handling Test Results

All data collected during these tests were copied to a USB flash drive in the field using the "Copy RMS Data" batch file from a shortcut on the Windows desktop. All data were successfully copied to the USB drive, and were brought into the office for further analysis. No data files were lost or corrupted in the process.

4.7 Data Analysis Results

4.7.1 Neutron Moisture Tool Calibration

The neutron moisture tool was calibrated by collecting data in the Hanford moisture calibration models. These models consist of steel cylinders filled with sand, with a steel-cased borehole along the vertical axis of the cylinder. Three models contain 8-in. internal-diameter (ID) casing with 0.322-in.-thick walls, and three contain 6-in. ID casing with 0.28-in.-thick walls. Moisture is simulated by $Al(OH)_3$ mixed with the sand. This provides a consistent response not subject to changes due to evaporation. The 6-in. ID casing most closely approximates a typical tank farm drywell, and RMS moisture calibration measurements were made in those models. Measurements were made in each model at equivalent volumetric moisture contents of 5, 11.7, and 19.8 percent. In addition, measurements were made with the sonde suspended in air. Although not used to develop the calibration equation, these measurements define the "air point" or detector response in zero moisture content. All measurements were made with a count time of approximately 15 sec.

Regression techniques were used to determine a response equation of the form:

$$VF = AR^B$$

Where VF is the volume fraction of moisture, R is the neutron count rate in cps, and A and B are constants. For the 6-in. ID borehole, the calibration data yielded:

$$A = 2.634E - 6 \quad B = 2.2014 \qquad (R^2 = 0.999)$$

Figure 1 shows a plot of the RMS moisture calibration data and the calibration function.

4.7.2 Gamma Tool Calibration Model Response

The RMS triple gamma tool contains three independent detectors: an NAI detector and two GM pairs, designated as GM1 and GM2. These detectors provide total gamma response only. Measurements were made in the Hanford gamma calibration standards to demonstrate linearity of response. Each standard is a cylindrical block of concrete with a 4.5-in. diameter test hole along the cylindrical axis. The standards are 4 or 5 ft in diameter and 4 ft tall, which is large enough to simulate an "infinite" medium in the sense that the gamma-ray flux within the test hole at the center of the standard is equivalent to that associated with a homogeneous medium of infinite extent. Varying levels of radioactivity are achieved by admixtures of orthoclase feldspar, uraninite, and monazite. Orthoclase feldspar contains potassium, of which about 0.01 percent is radioactive ^{40}K. Uraninite contains uranium (^{238}U and ^{235}U) with associated members of the uranium and actinium decay series, and monazite contains thorium (^{232}Th) with associated members of the thorium decay series. The use of the ore materials uraninite and monazite assures that secular equilibrium is established throughout each decay series, meaning that the activity of any daughter is equivalent to the activity of the parent. This provides a wide range of gamma rays at known energy levels and stable activity from which energy-dependent efficiency functions can be developed for spectral detectors. Activity values for the Hanford calibration standards are given in Table 4.1 (DOE 1986).

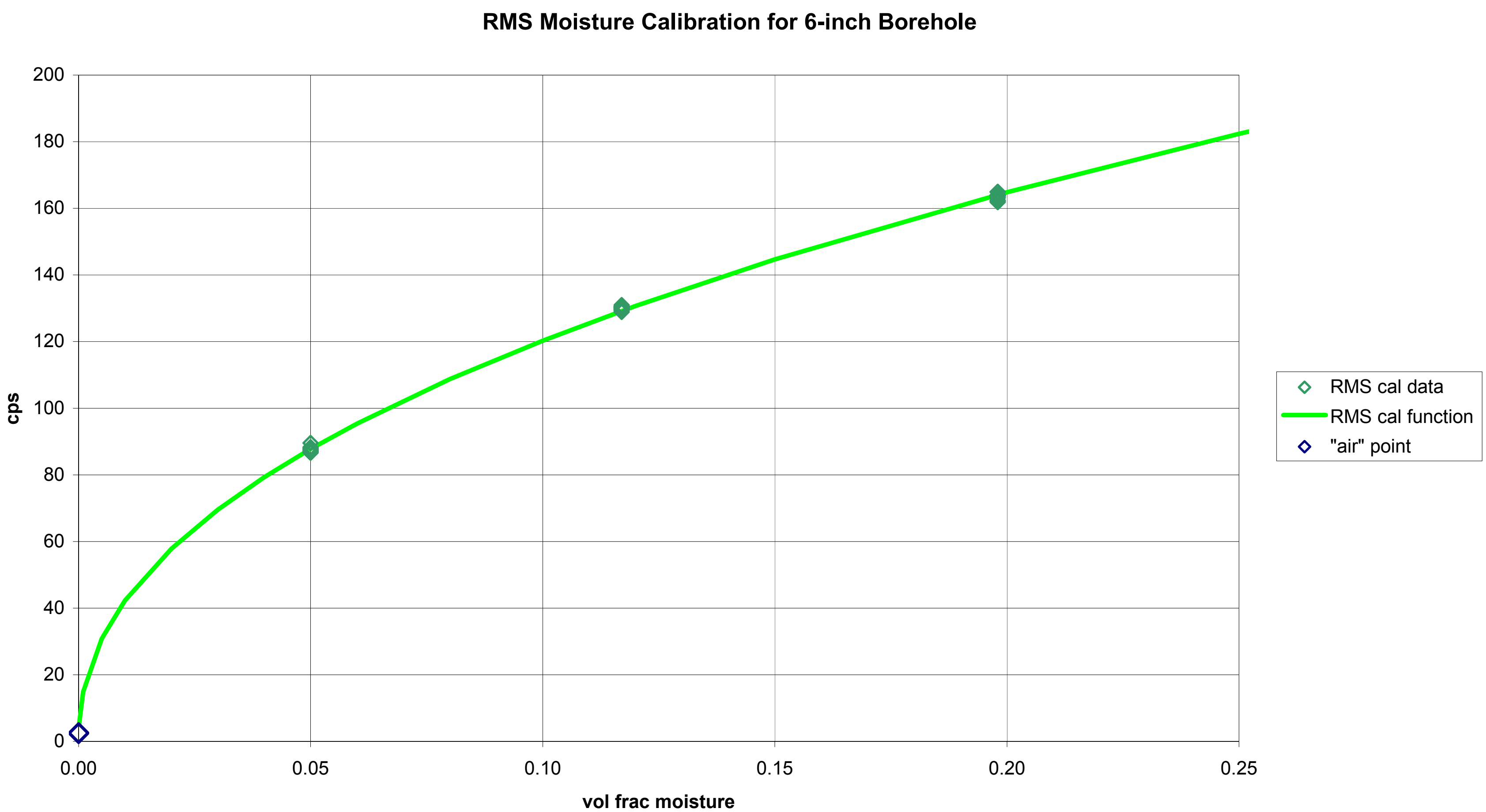

Figure 1. RMS Moisture Tool Calibration

Table 4.1 Activity values for the Hanford Calibration Models

Model	^{40}K (pCi/g)	^{226}Ra (^{238}U) (pCi/g)	^{232}Th (pCi/g)
SBT	10.6 ± 1.3	10.02 ± 0.48	58.1 ± 1.4
SBK	53.5 ± 1.7	1.16 ± 0.11	0.11 ± 0.02
SBU	10.7 ± 0.8	190.5 ± 5.8	0.66 ± 0.06
SBM	41.8 ± 1.8	125.8 ± 4.0	39.1 ± 1.1
SBL	undetermined	324.0 ± 9.0	undetermined
SBH	undetermined	3126 ± 180	undetermined
SBA	undetermined	61.2 ± 1.7	undetermined
SBB	undetermined	902.0 ± 27.0	undetermined

The triple gamma tool used in the RMS is not capable of energy discrimination, and each detector response is stated in terms of total count rate. Each detector should exhibit a linear response to increasing radioactivity, with deviations near background and at the upper end of its measurement range. However, detector efficiency depends on the energy of the incident gamma ray, and it can be misleading to compare response to activity at different energy levels. Four of the calibration standards (SBL, SBH, SBA, and SBB) contain only uraninite, and a fifth (SBU) is predominantly uraninite so that radioactivity in these standards is associated primarily with uranium content. In addition the "air point" measurements can be used to establish background count rates for each of the detectors.

Figure 2 shows the total count rate response of each detector plotted against "equivalent uranium" (eU) values for the calibration standards. Also plotted are "calibration lines" for each detector. These are determined by a linear regression to data from the SBA, SBU, SBL, and SBB standards; the SBH is not used because it is possible that self-absorption associated with a higher average atomic number may affect gamma intensity in the borehole. For each plot, the larger solid symbols represent data used to derive the calibration line, while the smaller open symbols indicate data from other standards. Each detector exhibits good linear response in the range of 100 to 1000 pCi/g eU. Below 100 pCi/g eU, the linear relationship is affected by the background count rate. Above about 1000 pCi/g eU, it appears that linearity may be affected by self-absorption and/or detector paralysis.

4.7.3 Results from Borehole 299-W10-72

The RMS operational test included logs in borehole 299-W10-72, which is located in the 216-T-7-tile field, near the southwest corner of the 241-T Tank Farm. This borehole was selected as a demonstration site because it is known to contain relatively high levels of ^{137}Cs and the overall borehole configuration closely approximates a tank farm drywell. RMS logs from this hole are compared to SGLS, HRLS data on Figure 3, and to a NMLS log on Figure 4.

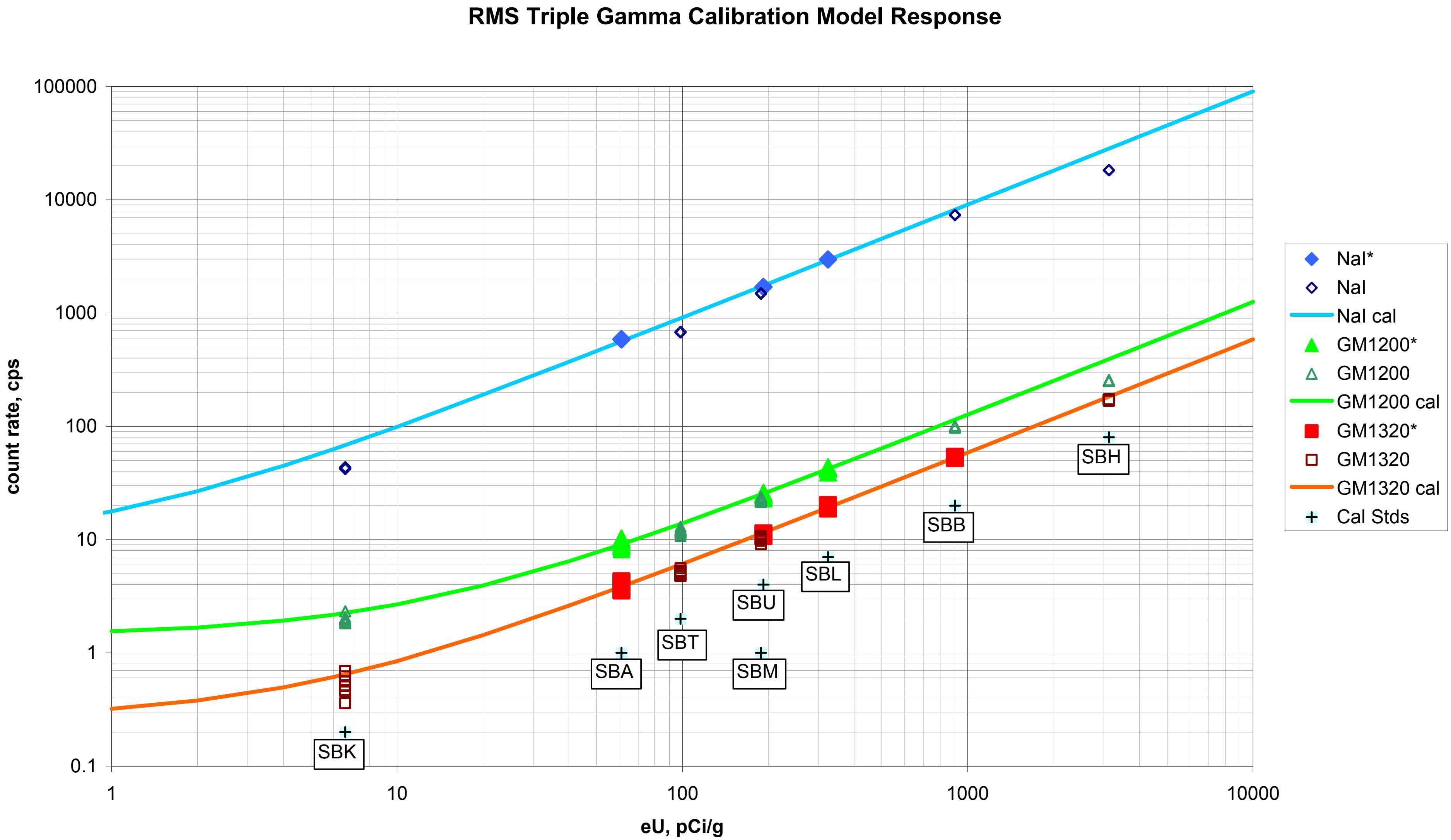

Figure 2. RMS Triple Gamma Tool Calibration Model Response Curves

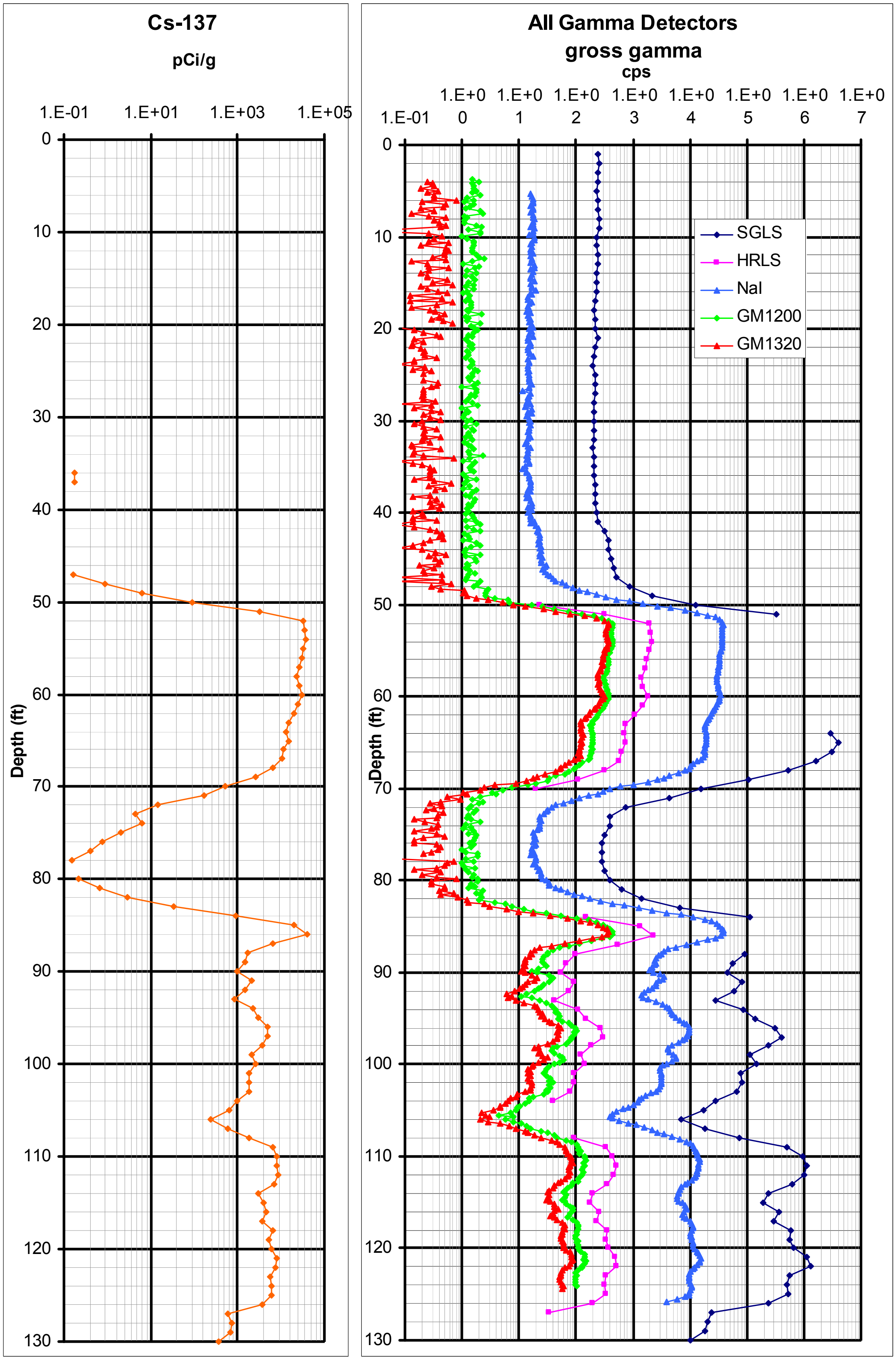

Figure 3. RMS, SGLS, and HRLS Gross Gamma Logs of 299-W10-72 Compared Against Cs-137

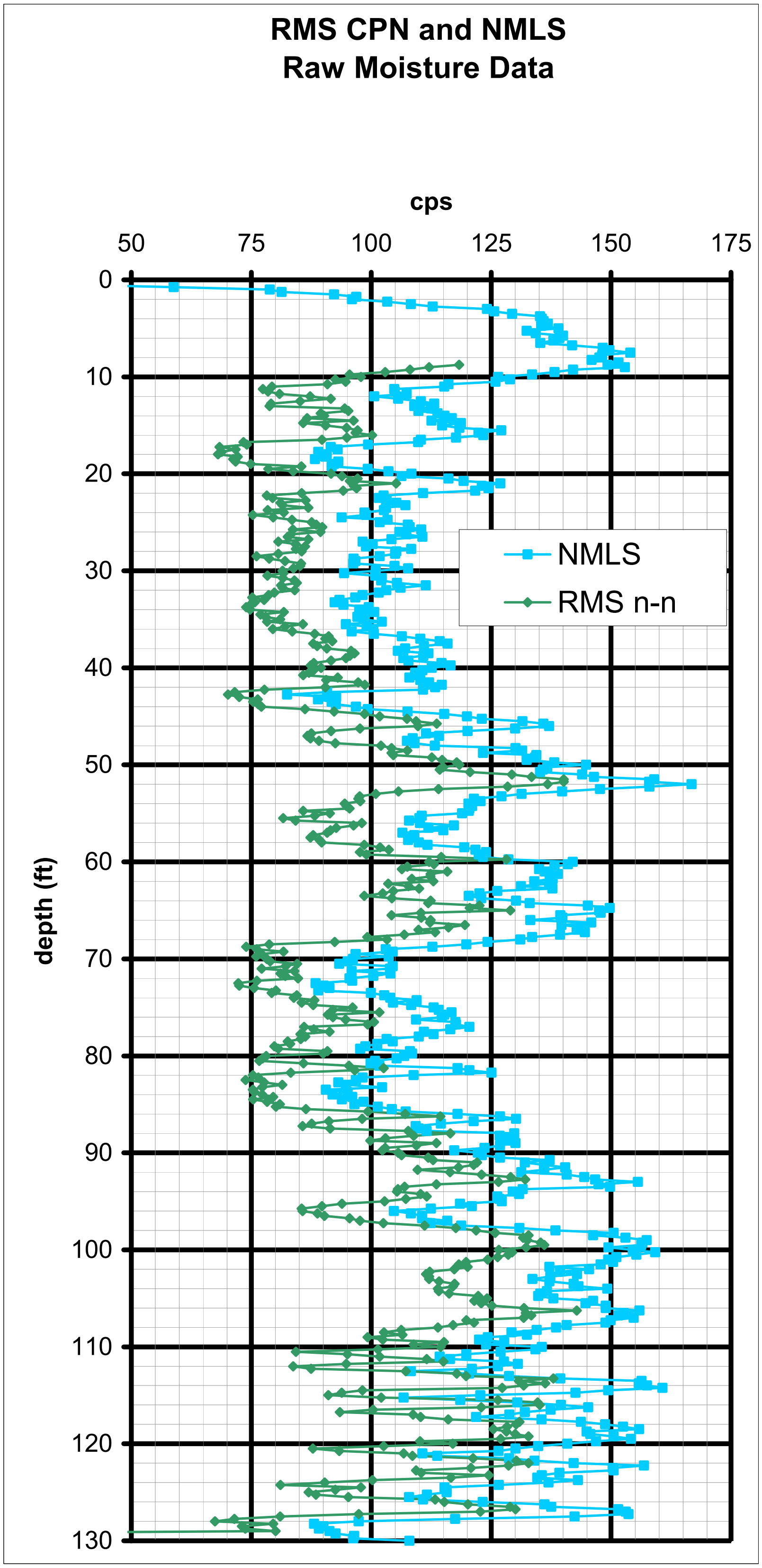

Figure 4. RMS Moisture Tool and NMLS Raw Counts from 299-W10-72

Figure 3 also shows ^{137}Cs concentrations from conventional SGLS and HRLS logs. Total gamma counts for the SGLS and HRLS are plotted for comparison on the right track. All three RMS detectors exhibit similar character when compared to the SGLS and HRLS logs and clearly reflect ^{137}Cs concentrations above 10 to 100 pCi/g. Note that the NaI detector provides a useful response even in intervals where the SGLS is saturated, and that both GM detectors "track" the HRLS response in the high-rate zone. GM response is approximately an order of magnitude less than that of the HRLS. Figure 5 shows the response of the two GM detectors in the triple gamma tool plotted as a function of ^{137}Cs concentration in 299-W10-72. Linear response curves are calculated by least-squares regression. These take into account the effects of the sonde housing and a typical borehole environment. Evaluation of detector response curves provided by the vendor suggests that both GM detectors provide a linear response for count rates up to approximately 1 E4 cps. Extrapolating the response curves derived from operational test data in 299-W10-72 suggests the triple gamma tool will provide a linear response up to approximately 1 E6 pCi/g ^{137}Cs. Maximum observed ^{137}Cs concentrations in the vadose zone in tank farms are on the order of 1 E9 pCi/g, based on HRLS measurements.

Experience with the HRLS indicates that shielding can be used to reduce detector response by about two orders of magnitude. This suggests that addition of external shielding may help extend the dynamic range of the triple gamma tool from background levels to the equivalent of about 1 E8 pCi/g ^{137}Cs concentration.

Evaluation of the neutron moisture response in 299-W10-72 (shown on Figure 4) indicates that the RMS neutron response closely follows that of the NMLS, albeit at a lower count rate. 299-W10-72 is 8-in. in diameter, and the RMS was only calibrated for a 6-in. diameter borehole, so it is impossible to compare moisture values. Careful comparison between the RMS moisture data and the NMLS log indicates that the RMS data may show better detail, particularly in complex thinly bedded intervals. One reason for this may be that the RMS was run without a centralizer. Over much of the hole, the sonde would likely run against the borehole wall and this may have improved response to thin beds.

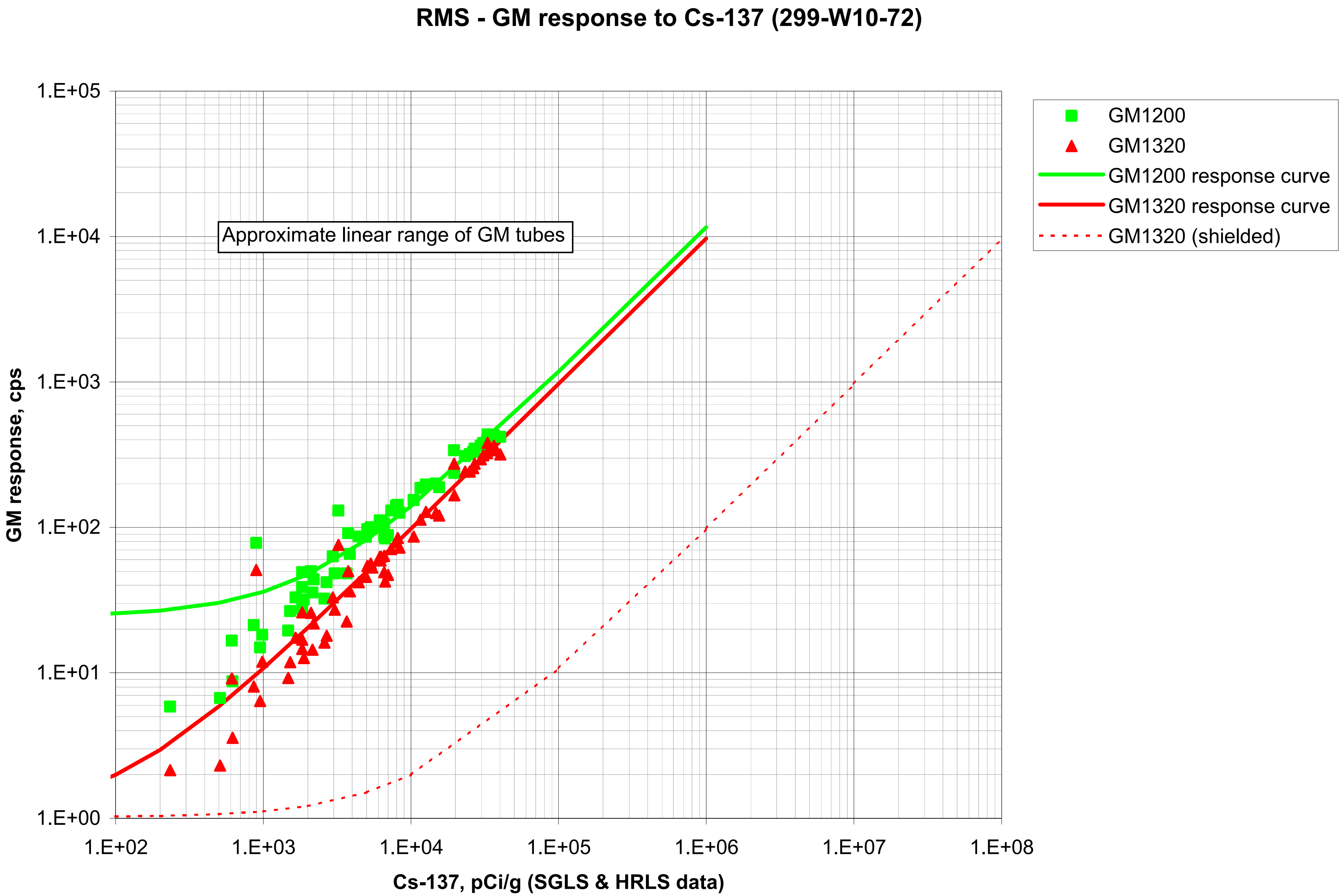

Figure 5. RMS GM Tool – Cs-137 Cross Plots

5.0 Miscellaneous System Problems

The following table describes miscellaneous problems with the logging system that were encountered while performing the operational test, at other times when the system was used (e.g., during calibration of the system at the Hanford Calibration Models), and during a preliminary testing of the operator procedures at the 272-WA garage. Resolution of each problem is included where applicable.

Table 5.1 Logging System Problems

System Problem	Resolution
The ergonomics of operating the system is poor. Operators must stand to operate all components of the system.	The use of a different vehicle is currently not an option. Standing is not constantly required, assuming that chairs are available. Collapsible chairs could be taken along to provide places to sit when standing is not required.
The laptop computer sits on top of the winch console, and could be blown off or knocked off inadvertently.	A velcro adhesive tape was added to the top of the console and the bottom of the computer, which keeps the computer in place quite effectively.
There is no storage room on the vehicle for tools and supplies.	A portable metal box was added to contain small parts, and the conex in which the system will be stored when not in use can be used for any larger supplies.
Because it is lightweight, the tripod is capable of moving away from the borehole under the weight of the tool during logging.	Something as simple as a sandbag can be placed at the end of the tripod to prevent motion during logging. This has been added to the list of additional required equipment for the system.
The winch system lacks a load sensitive device that will stop cable spooling when the sonde reaches the bottom of the borehole and when it returns to the surface. This is a safety issue and is particularly important to prevent the cablehead from being pulled through the sheave wheel assembly.	Simple vigilance and care is required to avoid these problems. Brightly colored bands of tape were wrapped around the cable at the 2- and 10-foot locations as additional visual cues that the tool is about to reach the top of the borehole.
The first line of data gathered during any log often contains spurious values.	The problem is likely a software issue that would be costly and time consuming to resolve. The best solution is to routinely throw out the first line of data from any log gathered with the RMS.

6.0 Conclusions

Operational testing of the RMS identified a small number of minor deficiencies and problems that were corrected where feasible. These changes were summarized in Section 5.0 of this report. rocedures have been written to reflect the configuration and capability of the RMS in its present condition, and sufficient data have been obtained with each of the four detectors to develop a data analysis method and calibration report. Data gathered using the RMS meet or exceed the requirements described in the OTP (DOE 2005).

The RMS is now considered operational, and plans are being made to train tank farm operational personnel to run the system.

7.0 References

U.S. Department of Energy (DOE), 1986. *Field Calibration Facilities for Environmental Measurement of Radium, Thorium and Potassium*, GJ/TMC-01 UC-70A, 2nd edition, prepared by Bendix Field Engineering Corporation for the Grand Junction Office, Grand Junction, Colorado.

_________, 2005. *Hanford Tank Farms Vadose Zone Monitoring Project Retrieval Monitoring System (RMS) Operational Test Plan*, DOE-EM/GJ910-2005, Rev. 0, prepared by S.M. Stoller Corporation for the Grand Junction Office, Grand Junction, Colorado.

Appendix A
Test Results Summary Sheets